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FRUIT JUICE CONCENTRATES

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of Division of Viticulture and Fruit Products

The investigations reported in this publication supplement those of Bulletin 359, Fruit Beverage Investigations, of this Station. The latter gave the results of experiments on the preparation of carbonated beverages, while the present deals principally with the preparation of concentrated fruit juices from which carbonated beverages and other products can be made.

Relation to the Fruit Industry.—Crop reports show that a surplus of apples, berries, citrus fruits, grapes and pomegranates frequently exists in California. This surplus usually consists of over-sized, under-sized, malformed and blemished but sound fruit "culls" which is not readily marketable in the fresh state. The disposal of this surplus profitably already constitutes one of the important problems of the fruit industry in spite of the fact that large acreages of some of the fruits have not yet come into bearing. This problem will probably become more acute as production increases. It is believed that the marketing of surplus fruits in the form of concentrated juices affords a promising outlet for much of the surplus, both present and impending.

Although large amounts of fruit are utilized every year in the manufacture of vinegar and fruit juice for local consumption, the preparation of jams, jellies, preserves, low grade canned fruit, etc., there still remains a large and growing surplus which is either not utilized or is often sold fresh in competition with and to the detriment of graded fruit.

Accurate data on the amount of surplus of all fruits are not available. However, a reliable estimate by the Division of Subtropical Horticulture has been obtained for oranges, lemons and pomegranates. An annual production of about 96,000 tons of cull oranges and 41,000 tons of cull lemons is estimated. If a larger proportion of the total crop were "culled" the growers would probably realize a greater profit from their good fruit. About 300 tons, or about 20 per cent, of the pomegranate crop was culled last year.

It is estimated that the average annual production of waste apples in the United States is 500,000 tons and in California it probably amounts to at least 75,000 tons. Cull apples are at present utilized in making vinegar, sweet cider and evaporated apples. Nevertheless, the use of part of the crop for concentrated juice for beverage purposes might increase the total returns from apple culls.

The term *concentrates* as used in this publication refers to fruit juices which have been concentrated by the removal of water either by the application of heat or by freezing.

If the juice from these waste fruits had been converted into concentrates for use in carbonated beverages it would have yielded the following amounts of concentrates and beverages made from concentrates:

Possible Yields of Concentrates and Beverages from Cull Fruits

Fruit	Tons of fruit	Gallons of concentrate	Number of 6½-oz. bottles of beverage	Value of beverages at 5c a bottle[2]	Value of concentrates, approximately
Oranges	96,000	1,920,000	864,000,000	$43,200,000	$7,000,000
Lemons	41,000	1,000,000	1,476,000,000	73,800,000	
Pomegranates	300	7,500	1,000,000	50,000	30,000
Grapes[1]	260,000	7,812,510	1,000,000,000	50,000,000	10,000,000
Apples, California	75,000	2,250,000	191,250,000	9,562,500	3,000,000
Apples, U. S. outside of California.	425,000	12,750,000	1,083,750,000	54,187,500	16,000,000

[1] Includes cull table grapes and raisins used for by-products.

[2] Retail value; wholesale value probably about one-half retail value.

The table does not include Florida citrus fruits, Hawaiian pineapples, Pacific Coast berries and cherries of the Eastern United States, all of which are important potential sources of fruit concentrates.

Relation to the Beverage Industry.—That there exists a large potential market for surplus fruits in the form of concentrated juice for use in the beverage industry is shown by the following consideration. There were consumed in the United States last year about 8,000,000,000 bottles of carbonated beverages or about 333,000,000 cases of 24 bottles each. It cost at least 80c to produce each case. The total cost to the bottler, therefore, was not less than $266,400,000. The retail value at $1.20 a case represents a total of about $400,000,000. The carbonated beverage industry is still growing rapidly. If all of the surplus fruit in the United States were available for beverage purposes, approximately one-half of the demand for carbonated beverages could be met; but a large proportion of the surplus of various fruits is not available for beverage purposes because it is utilized in other ways. If only one-fourth of the synthetic carbonated beverages could be supplanted by fruit beverages it would provide a profitable means of disposing of the greater part of the present surplus of fruit.

The bottlers of carbonated beverages now use synthetic syrups that permit of great dilution during carbonating and bottling. In order that their present equipment might be used efficiently with pure fruit products it is necessary that such products be furnished in highly concentrated form.

Uses for Fruit Concentrates.—Fruit concentrates have a wide variety of uses in the preparation of beverages and foods. Of these the most important are carbonated and non-carbonated beverages, jellies, gelatin desserts, ice cream, candy and numerous cooked foods.

Methods of Producing Fruit Concentrates.—Several methods have been devised for the concentration of fruit juices. Some of these are not practicable commercially, while others have proved satisfactory and are now being used extensively in the commercial production of concentrates.

1. *Concentration by Heat at Atmospheric Pressure.*—By this method fruit juices are concentrated in various types of open concentrators, such as direct-fired kettles, sorghum pans, steam-heated pans, steam-jacketed kettles and kettles heated by steam coils. Because the delicate flavor and color of most fruit juices is easily injured by heat, these methods have not proved satisfactory in the production of fruit concentrates for use in the beverage industry. Boiled cider is made in open concentrators, but is commonly used in the manufacture of mince meat and the aroma of the original juice is not required in the finished product. "Moskyfat," a grape product of South Africa, consists of grape juice concentrated in the open. It has a characteristic caramelized flavor and brownish red color and although not suitable for carbonated beverages, is satisfactory for cooking purposes.

2. *Concentration by Solar Heat.*—This method has given fair results on a small scale but has not been adopted commercially. From the standpoint of the bottler the method is objectionable because during concentration the juice is much oxidized and loses both its fresh flavor and color. It is only suitable for concentrating juices for cooking purposes and table use.

3. *Spray Process.*—Fruit juice may be concentratd by the "spray-milk drying" process but usually the addition of glucose, cane sugar dextrine or other "drying" agent is necessary to prevent the formation of syrup after drying. The Merrill-Soule Company of New York has successfully reduced orange and lemon juices to powdered form by this process. The lemon powder reduced in this manner is a fairly satisfactory product and could undoubtedly be used in preparing carbonated beverages. The orange juice powder samples tested are

decidedly lacking in flavor and unless the quality can be improved would not be very suitable for beverage purposes.

4. *Concentration by Freezing.*—This process is the best for preserving the aroma and color of the original fruit. It has been studied by Eudo Monti in Italy and H. C. Gore in the United States. According to Gore's process the fruit juice is placed in ice cans and frozen to a solid cake of ice. The ice is then broken up and placed in a centrifuge basket which is operated at a moderate speed. The whirling of the centrifuge forces the syrup through the perforations of the basket and separates it from the ice crystals. By two or three successive freezings and centrifugings, the juice is concentrated to 50°-55° Balling. This or a similar method has been used successfully in the Hawaiian Islands for the concentration of pineapple juice although marketing of the syrup has been difficult.

The Monti process is continuous and the syrup is separated from the ice crystals by draining or otherwise. The centrifuge is not used. Professor Eudo Monti states that this process is used commercially in Italy for the preparation of grape syrup.

5. *The "Ice Plant Process."*—In coöperation with the Lindsay Farm Bureau and Community Ice Company of Lindsay, I have been able to develop a process for concentrating pomegranate juice by freezing which eliminates several of the difficulties encountered in the other freezing processes. This process is applicable to nearly all fruit juices. It is described on pages 11–13.

6. *Concentration in Vacuo.*—Concentration at atmospheric pressure results in the loss of flavor and color and often in caramelization. Some of these difficulties may be avoided by concentrating under vacuum. Under a vacuum, liquids boil at a lower temperature than in the open and the moisture is removed with less injury to the juice. "Vacuum pan" is the name applied to the commercial apparatus utilizing this principle. There are many vacuum pans in operation in sugar refineries, milk concentrating plants and fruit juice concentrating plants in this state. This apparatus is the one most extensively used in the commercial production of fruit concentrates at present.

Vacuum pans vary greatly in materials of construction and in general design. The simplest apparatus consists of a steam jacketed, enclosed, cylindrical tank with curved bottom and connected through a vapor condenser to a pump which exhausts the air from the apparatus and maintains it under a vacuum. In most commercial vacuum pans in addition to the steam jacket, or replacing it, are steam coils, or a steam calandria which consists of vertical, steam jacketed tubes

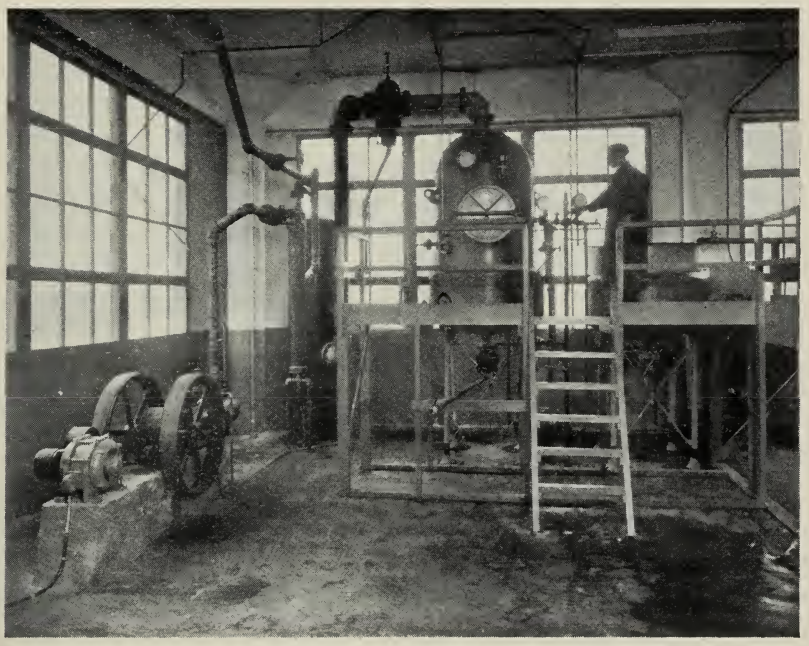

Fig. 1.—The Pfaudler Pre-heater with the Pfaudler Vacuum Pan. By courtesy of the Pfaudler Company of Rochester, N. Y.

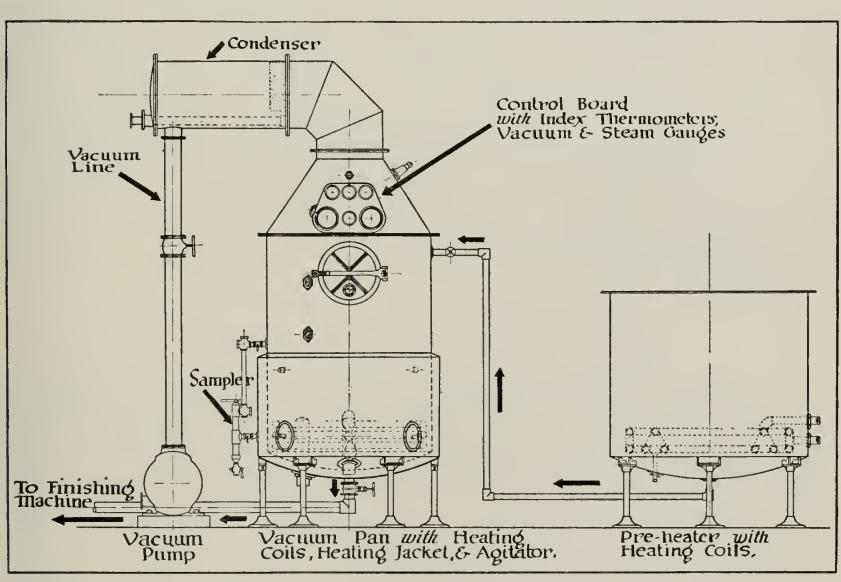

Fig. 2.—Diagram shows "hook-up" of Pfaudler Pre-heater with Pfaudler Vacuum Pan. By courtesy of the Pfaudler Company of Rochester, N. Y.

placed inside the pan. Figure 1 is a glass enameled vacuum equipment of which figure 2 is a diagramatic sketch.

In another type of vacuum pan the liquid travels upward by ebullition through a steam or hot water jacketed pipe or series of pipes and emerges in concentrated form. In another similar apparatus the liquid travels downward. These are known as ascending and descending film evaporators respectively. In them the liquid is subjected to the evaporating temperature for a very short time only, so that injury by heat is much reduced.

A very successful vaccum pan for fruit juices is that known as the "Peebles Evaporator." (See fig. 3) In this apparatus the juice is heated to a relatively high temperature outside the vacuum pan proper and is then sprayed into the evaporating chamber where the great rapidity of evaporation reduces the temperature of the juice instantly.

It will not be possible in this publication, because of lack of space to describe fully the mechanical features and operation of all vacuum pans. Those who contemplate installing such equipment will be furnished references on the subject and assisted in other ways in obtaining further information.

Recovery of Aroma.—A large part of the aroma of fruit juices consists of volatile flavoring compounds which are readily destroyed or driven off by heating, even *in vacuo*. It is possible to recover a portion of these volatile compounds by collecting the distillate and redistilling it at a higher temperature than was used in concentrating the juice. These compounds volatilize early in the concentrating process. Most of the aroma volatilizes during the first few minutes so that it may be recovered in a small amount of the water distillate. M. K. Serailian of San Francisco has developed a continuous process by which the aroma may be recovered and returned to the concentrate automatically.

REPORT OF INVESTIGATIONS

In order to determine the most satisfactory methods of preparing fruit concentrates a series of experiments have been conducted in the Fruit Products Laboratory of the University and in commercial factories during the past three years. The principal results are reported in this publication.

Standardization of Fruit Concentrates.—Fruit juices from different localities from fruit at different stages of maturity and produced under different cultural methods vary greatly in sugar and acid

content so that standardization of concentrates made from such juices demands careful attention. As a result of many experiments and observations the following information was obtained.

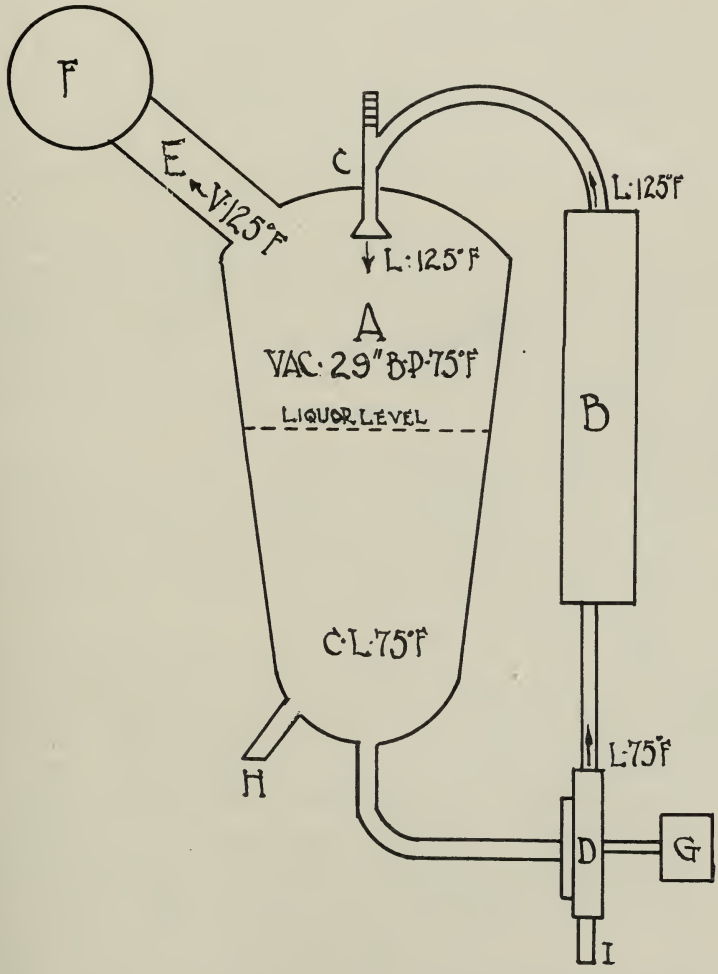

Fig. 3.—A diagramatic sketch of a Peebles Single Effect Evaporator. It consists of the expansion chamber (A) and the tubular heater (B). The expansion chamber (A) is sealed with a spring seating valve (C) and a centrifugal pump (D), the latter designed to operate with vacuum on the intake side and against pressure on the discharge side. The vapor line (E) conducts the generated vapors to the condensing system (F), which also includes the means for creating and maintaining the vacuum. The inlet (H) is used for filling the expansion chamber (A) and the outlet (I) permits the discharge of the concentrated material. The heater (B) is heated by steam. The pump (D) is driven by motor (G). The concentrating liquor (C L) enters the heater (B) at 75° F. and leaves it at 125° F.

Some juices such as apple and loganberry made from immature fruit will jellify when a concentration of 60° to 75° F. Balling is reached, which is objectionable because of the difficulty of redissolving. This can be avoided by deacidifying with calcium carbonate. There is danger of introducing foreign flavors by doing this, however, and of reducing the amount of dilution that the juice will bear. A better plan is to concentrate to only 55° Balling or less.

For concentrated orange juice a standard soluble solid (sugar) and acid ratio of 12 to 1 at 72° Balling has been adopted by one commercial firm. The slight deficiency in sugar is made up by adding cane sugar.

Lemon juice should be concentrated to 72° Balling or about 35 per cent acidity. Grape juice should be concentrated to 67–68° Balling and preserved by pasteurizing or other means. Above 68° Balling it is apt to crystallize. Pomegranate juice should be concentrated to 65° Balling. A satisfactory pineapple concentrate of 75° Balling and 4 per cent acid has been used in these investigations. It is produced commercially.

The experiments show that the keeping quality of the color and flavor of some fruit concentrates is improved by the addition of cane sugar. The amount required varies with the variety of juice and its composition. The individual juices are discussed more fully under experiments on "Concentration in Vacuo."

Experiments on Concentration in Vacuo.—Experiments with this process were conducted by using two forms of small glass vacuum apparatus, a laboratory-size, tin-plated, copper vacuum pan and a glass enamel lined vacuum pan. In all experiments the best results were obtained in the glass and the glass enamel apparatus. The metal imparted a metallic taste and impaired the color of the concentrate.

One form of Glass Apparatus* was assembled in the laboratory on the principle of the descending film evaporator. It consisted of a one-inch outer glass tube which served as a steam jacket and an inner ¼-inch tube which served as a boiling tube and which was connected at one end to the juice supply and at the other to a receiving flask, condenser and vacuum pump. While the capacity was small the apparatus gave excellent results because the heating period was short. (See fig. 4.)

All juices were clarified before concentration. The difficulty of filtering highly concentrated juices because of their viscosity renders it necessary to clarify the juice before concentrating. The methods of filtration and clarification are described in detail in Bulletin 359.

* Assembled by W. V. Cruess.

Details of the vacuum concentration experiments are given under the individual fruits, pages 13–14.

Experiments on Concentration by the "Ice Plant Process."—The equipment for these experiments was that used in the commercial production of ice at Lindsay. The ice cans, which were made of sheet iron, were electro-plated with copper in order to prevent contact of the juice with the iron. The cans should be made of a metal or coated with a material that will not react with the acid of the juice, or injure

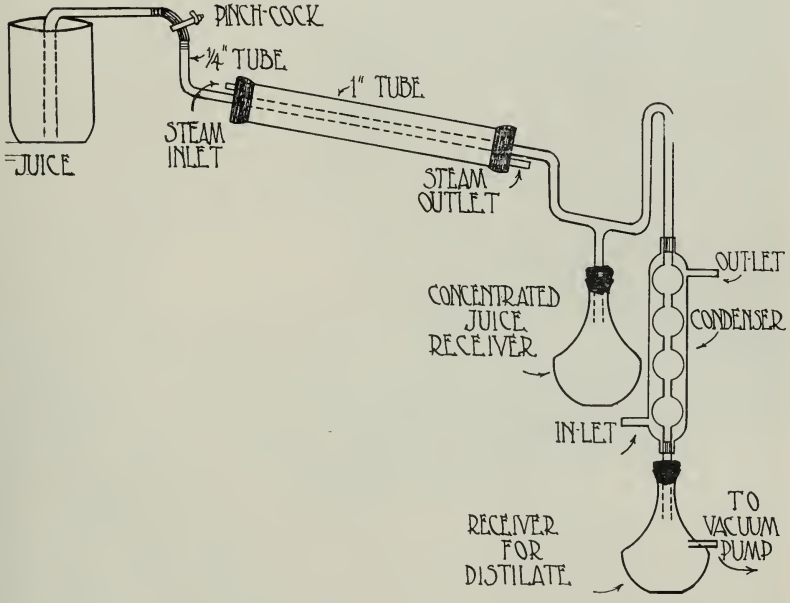

Fig. 4.—Glass vacuum apparatus used in laboratory experiments.

the color or flavor. Block-tin, monel-metal, silver and glass enamel are suitable for most juices. If corrodible metal cans only are available, frequent coating with lacquer or paraffiin will prevent excessive reaction between the metal and juice.

The air agitating device used in the manufacture of ice was placed in the bottom of the can of juice to be frozen. Ice formed first as a coating on the inside of the can. This coating increased in thickness until most of the water of the juice had frozen and had formed a solid cake of ice with a cavity at the bottom where the agitation had occurred. When the freezing was complete the syrup was siphoned off or drained from the ice. The cake of ice was then removed from the can and allowed to drain.

A concentrate of 42° Balling was obtained by one freezing of juice that was originally 17° Balling; 40 gallons of juice yielded 12 gallons of concentrate.

The experiment showed that air supplied to the agitator should be filtered. This can be done by enclosing the intake in a dust-proof

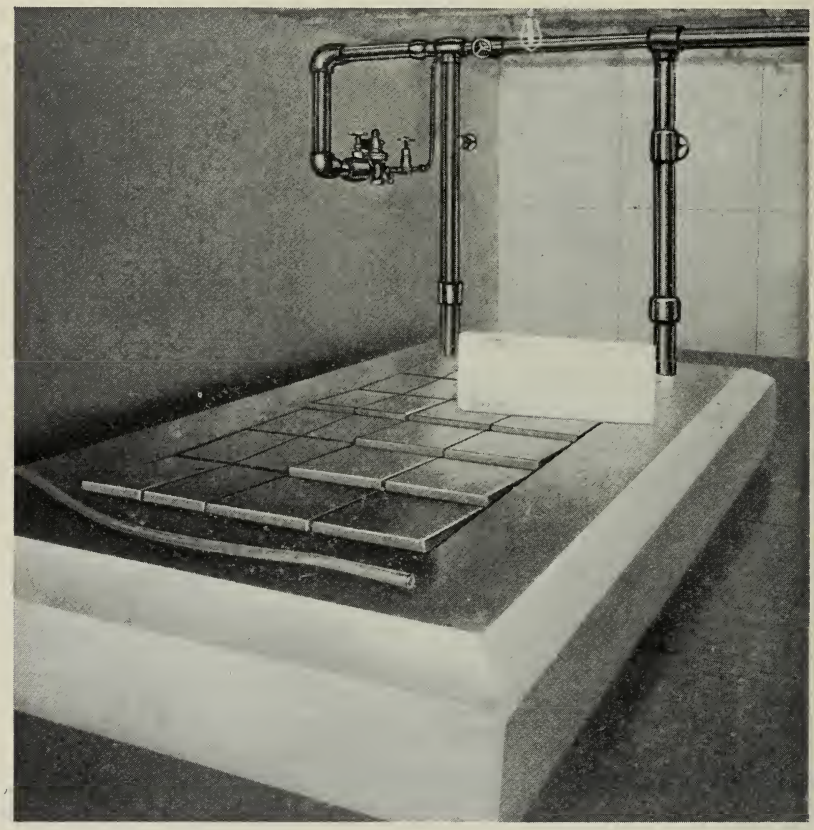

Fig. 5.—Ice making tanks. By courtesy of Automatic Refrigerator Company, Hartford, Conn.

box, filled with a filtering medium. In dry, dusty weather, without this precaution sufficient dust would be carried by the air into the juice to render it unfit for human consumption.

The Lindsay community ice plant has a capacity of nine tons of ice in 24 hours. At full capacity the plant is capable of concentrating the juice of 30 tons of pomegranates a day if full efficiency were realized.

Since many of the fruits suitable for juice are available in the fall and winter when the demand for ice is light, the ice making equipment might be used for the concentration of fruit juices with very little additional expense.

It is very probable that the adaptation of ice manufacturing equipment to the production of concentrates can be made decidedly profitable, largely because it would utilize the equipment during the idle season.

The concentrates should be stored in hermetically sealed containers in freezing storage if it is desired to retain the full flavor and color. Concentrates prepared experimentally have been preserved for several months with fair success by pasteurization at 175° F., but after prolonged storage loss of color and flavor are apt to occur. See also page 18 on "Preservation of Fruit Concentrates."

CONCENTRATING VARIOUS FRUIT JUICES

1. *Grape.*—For use in beverages the most important classes of grapes are those having a strong distinctive flavor such as the Muscat and the Semillon, those of deep color but mild flavor such as the Alicante Bouschet and Petite Sirah and those of combined deep color and distinctive flavor such as the Pierce and Concord.

Concentrates were produced from the three classes. Juices of from 22° to 24° Balling, in optimum condition for the purpose, were concentrated to 72° Balling *in vacuo*. A blend of two parts of the concentrate of high flavor with one part of the color variety gave a syrup that made an excellent carbonated beverage on dilution with carbonated water. It was found that the acidity of grape concentrates was low owing to the precipitation of the cream of tartar. This deficiency may be made up by the addition of tartaric acid in amounts sufficient to meet the requirements of the product in which the concentrate is to be used. Pierce grape concentrate was fairly satisfactory although much of the flavor was lost by ordinary vacuum pan concentration.

2. *Apple.*—Apple juice of 14° Balling and .5 per cent acid was concentrated *in vacuo* to 60° Balling. This was found to be the best of the experimental apple concentrates for beverage purposes.

3. *Pomegranate.*—Pomegranate juice was concentrated in glass *in vacuo* to 72° Balling and reduced to 70° Balling by the addition of the redistilled condensate containing the aroma. While satisfactory for coloring other juices the pomegranate used alone lacked flavor.

4. *Berries.*—Using the glass and glass enamel vacuum apparatus, blackberry and loganberry juices were concentrated to 50° Balling and strawberry juice to 60° Balling. Concentrated blackberry juice was not found suitable for use in beverages because of the lack of distinctive flavor while the strawberry was deficient in color. However, when two parts of strawberry concentrate and one part of blackberry were combined, a beverage with a good strawberry flavor and a bright red color was obtained on dilution with water.

The loganberry possessed sufficient flavor and color of its own when bottled with carbonated water. While not equal to beverages made from the fresh juices those from the concentrated juices were very satisfactory. If prepared for sale, the blended blackberry and strawberry products would require on the label some such statement as "strawberry with blackberry."

EXPERIMENTS ON THE UTILIZATION OF FRUIT CONCENTRATES

Fruit concentrates can be easily transported and preserved for use in the manufacture of many products.

1. *Bottled Carbonated Beverages.*—This is probably the largest outlet for fruit concentrates since they are especially suitable for this purpose, and because the market has already been partially developed.

a. Orange, has proved the most popular and is the most extensively used of all fruit concentrates for beverage purposes. In our experiments a bottlers syrup was prepared according to the following formula:

1 gallon 72° Balling concentrate (prepared commercially at San Dimas, California).
5 gallons 60° Balling simple syrup (cane sugar and water).
7½ c.c orange oil (cold pressed California oil).
1½ ozs. of this syrup was added to each 6½-oz. bottle and carbonated water added under low pressure.

Orange requires low carbonation to produce the most palatable drink and one volume of gas was found sufficient. The carbonated bottled beverage was successfully pasteurized at 150° F., in 30 minutes and has retained its flavor and color very well in all cases for two months and in some cases much longer.

b. Lemon, because of its high acidity and distinctive flavor, was found one of the most satisfactory of all fruit concentrates tested and permitted of the greatest dilution. The following formula was found best:

1 gallon 72° Balling concentrate (from a commercial factory at San Dimas).

20 gallons, 60° Balling simple syrup.

20 c.c lemon oil (cold pressed California oil).

1½ ozs. of this syrup was added to each 6½-oz. bottle and carbonated 2 to 3 volumes of gas.

It also withstood pasteurization and retained its flavor for several months. The finished beverage is cloudy and on standing develops a slight deposit, but this readily goes into suspension on lightly shaking the bottle. The Henry Brown Co. of Glendale and the Imperial Soda Works of Oakland are successfully bottling both the lemon and the orange beverages prepared in the above or a similar manner.

c. Grape. The sugar content of grape concentrate was so high that it did not require the addition of simple syrup and was used according to the following formula:

1 gallon 72° Balling red grape concentrate for color;

2 gallons 72° Balling Muscat concentrate for flavor; both juices concentrated *in vacuo* at the Fruit Products Laboratory. The syrups were mixed thoroughly and 1 oz. was added to each 6½-oz. bottle and carbonated with 3 volumes of gas. When the carbon dioxide did not produce sufficient tartness the deficiency was made up by adding the required amount of tartaric acid.

This product was sold under the name of "Muscat Blend" to the campus public and was well received over a period of more than a year.

d. Apple. Like grape, apple did not require the addition of simple syrup.

1½ ozs. of 60° Balling apple concentrate was added to each 6½-oz. bottle and then filled with water carbonated with 3 volumes of gas. This produced a very fine beverage which withstood pasteurization and retained the quality perfectly during storage in the bottle.

The concentrate was prepared in the Fruit Products Laboratory from cull Newtown Pippin apples by the usual juice extraction methods, filtration, and concentration in a glass-lined vacuum pan.

e. Pomegranate. This was not found satisfactory for carbonated beverage. A still beverage was made as follows:

1 gallon 70° Balling concentrate.

4 gallons of water.

7½ lbs. sugar.

This was bottled in 6½-oz. bottles and pasteurized at 175° F., for 30 minutes. It has retained its color and flavor very well and produces on dilution an excellent drink. The syrup was made by pressing the whole fruit, heating to 175° F., cooling 24 hours, filtering and concentrating *in vacuo* in glass.

f. A strawberry-blackberry beverage was made as follows from concentrates prepared in the Fruit Products Laboratory:

2 gallons 60° Balling strawberry concentrate;
1 gallon 50° Balling blackberry concentrate; both syrups made by concentration *in vacuo.*
9 gallons 60° Balling simple syrup.
1½ ozs. of this syrup was added to each 6½-oz. bottle and filled with water carbonated with 3 volumes of gas. The bottled beverage was pasteurized at 150° F., for 30 minutes and has retained its original quality in a satisfactory manner.

g. A loganberry beverage was made as follows:

1 gallon 50° Balling loganberry concentrate made by concentration in a glass-lined vacuum pan.
5 gallons 60° Balling simple syrup.
1½ ozs. of this syrup was added to each 6½-oz. bottle and filled with water carbonated with 3 volumes of gas.

h. Cherry concentrate was prepared from ripe Black Tartarian cherries by crushing the fruit, heating to 212° F., on the pits, pressing, filtering and concentrating in a glass-lined vacuum pan to 65° Balling. It was used in several ways but was found best according to the following formula:

1 gallon 60° Balling cherry concentrate.
5 gallons 60° Balling simple syrup.
10 c.c. bitter almond oil.
1½ ozs. of this syrup was added to each 6½-oz. bottle and water carbonated with 3 volumes of gas added to fill the bottles.
NOTE: All carbonated fruit beverages require pasteurization for 30 minutes at 150° F., or the addition of $\frac{1}{10}$ of 1 per cent sodium benzoate for preservation.

In addition to the formulae given many others were tested. Those listed were found best.

2. *Fruit Concentrates for Punch.*—The great acidity of lemon concentrate renders it suitable for blending with other fruit concentrates to be used for making punch. In one case it was combined with orange and blackberry according to the following formula.*

2 gallons 72° Balling commercial lemon concentrate.
1 gallon 72° Balling commercial orange concentrate.
1 gallon 50° Balling blackberry concentrate (from laboratory experiments).
25 c.c lemon oil (cold pressed, California).

The composition of this blend was 66° Balling and 22 per cent total acidity as citric. It was found to keep without pasteurization because

* Such a blend was just suggested and prepared by W. V. Cruess in July, 1924.

of the high acidity but for safety in preparing it for sale it has been pasteurized at 175° F., for 30 minutes. It withstands pasteurizing and storage fairly well.

Punch was prepared from this syrup as follows:

1 gallon punch concentrate.
20 gallons water.
30 lbs. sugar.

Individual taste varies; some consumers prefer greater dilution, some less. The concentrate has been sold to numerous campus organizations and to many Berkeley families. It has proved very popular. A company in Los Angeles is now producing it and others are interested.

Pomegranate punch concentrate was prepared as follows:

1 gallon 72° Balling commercial lemon concentrate.
4 gallons 72° Balling pomegranate concentrate (made in the laboratory).

Punch was prepared according to the following formula:

1 gallon pomegranate punch concentrate.
20 gallons water.
15 lbs. sugar.

The drink was of excellent purplish red color, and good flavor; it was even superior to the blackberry-orange-lemon blend. Pomegranates are plentiful and cheap. The writer believes this blend has great commercial possibilities.

Many other combinations are possible and a number of these have been prepared. One of these is lemon-red grape-orange.

3. *Sherberts, Water Ices and Ice Cream.*—Fruit concentrates were found especially satisfactory for use in sherbets and water ices. Either a small quantity of the concentrate may be added to the sherbet stock or it may be diluted to about the strength of the original juice, sweetened when necessary and frozen. The color and flavor of the original juice is preserved in the finished product.

A delicious fruit flavored ice cream was produced by adding various concentrates to vanilla ice cream in sufficient amount to impart the characteristic flavor of the fruit. This work was conducted in the ice cream plant of the Dairy Division at Davis by Professor G. D. Turnbow and the writer. A more complete joint report will be made later on the use of fruits in this form and other forms in ice cream.

4. *In Candy.*—James B. Vance, a former graduate student assistant in this laboratory found that concentrated berry juices could be used successfully in preparing jellied fruit candy with sugar and pectin.

A. Roewade, former chief chemist for the Remar Candy Company, used berry concentrates successfully for flavoring cream centers for chocolate dipping. Other possible uses for fruit concentrates in candy are flavoring and coloring marshmallows, gum drops, fruit drops, etc.

5. *For Jelly.*—The concentrates have been used in the laboratory as a base for jellies. They were diluted with water; pectin and sugar were added and the mixture cooked to the jellying point. Very good jelly resulted. This suggested their use in the household with any of the household pectins now on the market to prepare jelly at any season of the year. It might also provide a means of supplying commercial jelly makers remote from fruit-growing sections, with jelly bases from all suitable varieties of fruit.

Preservation of Fruit Concentrates.—Fruit juices concentrated to 72° Balling do not spoil readily at moderate temperatures because most micro-organisms cannot live in juice of such high concentration. However, molding may sometimes occur in nearly all concentrates and fermentation in some. Some means of preservation is, therefore, desirable.

1. *Cold Storage.*—Tests made show that concentrates can be held indefinitely without spoilage in cold storage at 30° F. It is advisable, however, to seal the concentrates in glass, wooden or properly coated metal containers so that the absorption of odors and tastes is avoided. The containers must not be filled completely because expansion during freezing would cause breakage. Concentrates have been stored experimentally in this manner for more than a year without noticeable loss of color or flavor. It is to be preferred to pasteurization.

2. *Pasteurization.*—If concentrates are to be held indefinitely, subjected to moderately high temperatures, pasteurization will prevent spoiling. In experiments in this laboratory pasteurizing at 175° F., for the following times varying according to the size of the container was found effective:

4-oz. bottle	20 minutes
6-oz. bottle	25 minutes
Pint bottle	30 minutes
Quart bottle	35 minutes
½-gallon bottle	45 minutes
Gallon bottle	60 minutes

These pasteurizing times and temperatures were determined by extensive heat penetration studies.

Directions for pasteurization are given in detail in Bulletin 359 and Circular 220 of this station.

These publications will be sent free on application to the College of Agriculture, Berkeley.

3. Chemical Preservatives.--Shipment of concentrates to hot climates often necessitates the use of a chemical preservative. This is particularly necessary for barrel shipments. Sodium benzoate is used for this purpose and is permissible when its presence is stated on the label. State regulations vary regarding the use of preservatives and the regulations of the states into which the product is to be shipped should be studied and must be observed. The usual limit is $\frac{1}{10}$ of 1 per cent although some states, California among them, permit the use of more than $\frac{1}{10}$ of 1 per cent provided it is declared on the label.

Only chemically pure sodium benzoate of the best quality should be used. It should be free from odors of other drugs such as iodoform, creosote, etc., which impart very disagreeable tastes to the products. It is used at the rate of 5 ozs. of dry sodium benzoate dissolved in a small amount of water, to every 47 gallons of concentrate or 20 ozs. by weight of a 25 per cent solution.

COMMERCIAL PRODUCTION

Companies have been and are being organized for the production of fruit concentrates, while several established sweet cider companies are expanding and preparing to produce a full line of fruit concentrates. Several bottlers of carbonated beverages have undertaken the bottling of carbonated fruit beverages which require fruit concentrates. The use of fruit concentrates in carbonated beverages, therefore, is rapidly emerging from the experimental stage and their commercial development appears to be certain. This laboratory is in active touch with the principal producers of fruit concentrates and is coöperating with them to place the products on a successful commercial basis.

SUMMARY AND CONCLUSIONS

1. Fruit juices in concentrated form are more satisfactory than the non-concentrated juices for use in the commercial production of carbonated beverages, sherbets, water ices, candy and other products owing to saving in transportation and convenience in handling.

2. Our experiments have showed that excellent concentrates may be made from the juice of oranges, lemons, grapes, pomegranates, apples, raspberries, loganberries and blackberries. Strawberry concentrate lacked color but this deficiency was made up by the addition of blackberry concentrate.

3. Concentration by freezing was found to be the best method for the preservation of the color and flavor of the fresh juice but did not yield so high a concentration as vacuum concentration.

4. Concentration *in vacuo* in a glass-lined vacuum pan was found to be the most practical method for concentrating all juices that were studied.

5. The aroma of the fresh juice lost during concentration may be recovered from the condensate by redistillation and may then be returned to the concentrate.

6. Test sales to consumers and observations on recent commercial developments indicate that carbonated beverages made from fruit juice concentrates will find a large market.

7. The difference in the consistency of various juices renders it impracticable to establish a standard of concentration to which all juices can be made to conform. However, it is possible to establish reasonably narrow limits for each individual fruit. This is desirable.

8. Lemon concentrate because of its great acidity is excellent for combining with other fruit concentrates for fruit punch concentrate to be used in soda fountains, in bottling works and in the home.

9. Concentrates should be stored in sealed containers to prevent the absorption of disagreeable odors when cold storage is used as a means of preservation.

10. Several methods of preservation are available. A concentrate of 72° Balling will keep several weeks at ordinary temperatures without spoiling. Cold storage at a temperature of 32° F., or lower will preserve it indefinitely.

If concentrates are to be shipped to tropical climates in containers that may permit infection with yeast or mold, sodium benzoate should be used as a preservative.

Pasteurization at 175° F., is a safe means of preserving fruit concentrates but storage at room temperature results in some loss of color and change in flavor.

11. Experiments and observations indicate that the preparation of fruit concentrates may provide an outlet for much of the state's surplus fruits.

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